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# MADRAS RECORD OFFICE.

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## Government of Madras.

Public works DEPARTMENT.

G.O. No. 2427-28 Press/Mis.
261, 262, 263, 263A
264, 265

Dated 15-10- 1878.

**Not to be folded or roughly handled**

Read the following papers:—

No. 261. From Captain J. PENNYCUICK, R.E., Executive Engineer in charge of Dindigul Range, Madura District, to the Secretary to Government, Public Works Department, dated Camp at Pulkanooth, 1st June 1872, No. 136.

I HAVE just received your telegram of the 27th ultimo, regarding the Vellaur Bridge Report.

2. It would be a useless waste of time and money to reply by telegraph, as the post is as quick.

3. The draft report was forwarded by me to Mr. Logan on the 6th March 1872 (four days after the final examination of the bridge), but the papers were not returned to me by Mr. Robinson, the other member of the Committee, until just as I was leaving Madras at the beginning of April.

4. Since then I have been so much on the move (having had to go first to Madura and then to Dindigul) and have been so occupied with taking charge of this enormous range, that I have not been able to attend to the papers again until quite lately.

5. Moreover, the difficulty of getting any clerical assistance in Dindigul is so great (the range establishment being quite unequal to its ordinary work) that it is only by the courtesy of the Sub-Collector that I have been able to get the papers copied at all. The fair copy is now being written, and I expect to receive it daily.

6. As soon as it is completed it will be forwarded to Messrs. Logan and Robinson for signature, and the latter will be asked to forward it direct to you.

7. I warned Colonel Carpendale that my leaving Madras to take over a range in Madura might very likely lead to some delay in the submission of this report; but his reply was to the effect that this was of less consequence than the loss of my services by my remaining in Madras.

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No. 262. *Report of Committee assembled to investigate the causes of destruction of the Bridge over the Vellaur River, on the coast road from Negapatam to Pondicherry.*

THE earliest record on the subject of this bridge which the Committee have been able to find in the Superintending Engineer's Office, 5th Division, is an order of the Government of India* sanctioning the entry in the Budget for 1856-57 of an estimate of Rupees 35,020 for its construction.

* Precis of correspondence, No. 1.

2. For some reason which does not appear from the correspondence, probably from want of funds, the work was not executed in 1856-57, and the subject appears to have dropped until 1862, when a revised plan and estimate (the latter still amounting to Rupees 35,020) were submitted, and after some correspondence,* sanctioned for entry in Budget of 1863-64.

* Precis of correspondence, No. 4—14.

3. The Budget allotment for that year appears to have been afterwards reduced, as we find a little later an order of Government* deferring on this ground sanction to an estimate of Rupees 40,000 for an iron screw pile bridge,

* Precis of correspondence, No. 19.

proposed by the Deputy Chief Engineer of the Southern Circle (Colonel Ouchterlony) to be substituted for the masonry one.

4. Colonel Ouchterlony appears to have been strongly impressed with the desirability of substituting an iron for a masonry bridge, and to have pressed the proposal in spite of the objections of the District Engineer, who considered that the former would be unduly expensive; the result of the correspondence was the submission to Government* of the estimate of Rupees 40,000, referred to in the preceding paragraph, for an iron girder bridge carried on iron screw piles.

* Precis of correspondence, No. 9—20.

5. After this the subject seems to have dropped again, with the exception of a few communications which passed between the Civil and Public Works Officers of the district, until 1867, when the plan was again taken up and revised, and, after some discussion, forwarded to Government for sanction; the estimate, amounting to Rupees 44,800, being sanctioned on the 9th August 1867 for entry in the Budget of 1868-69. This estimate was afterwards revised, and an addition made to it of Rupees 9,130, due chiefly to an increase in the rates for brick work and for sinking wells.

Precis of correspondence, No. 21—25.

Precis of correspondence, No. 26—39.

6. The bridge was accordingly commenced in April 1869, and completed in October 1871. The details of the completion of the several parts of the bridge, and the work done during the different seasons, are given in the annexed statement.

Marked B.

7. According to the original design the bridge was to consist of nine elliptical arches of 55 feet span and 13 feet 9 inches rise, with piers 8 feet 3 inches up to springing, giving a total waterway of 4,084 square feet below springing, and 5,346 square feet above. The piers were to be 7 feet thick and the arch work 2 feet 3 inches.

8. The revised plan sanctioned in 1862 consisted of eleven segmental arches of 45 feet span, and 9 feet rise, piers 11 feet high, giving an area of waterway of 5,445 square feet below, and 2,745 square feet above the springing.

9. The revised plan forwarded in 1867 and finally sanctioned by Government consisted of eleven elliptical arches of 45 feet span and $11\frac{1}{4}$ feet rise, piers 12 feet high; a further addition of $1\frac{1}{2}$ feet was made to the height of the piers during construction by order of Colonel Boileau, so that the bridge, as finally constructed, had a waterway of 6,682 square feet below springing and 4,374 square feet above. The piers were 6 feet thick and the arch work 1 foot $10\frac{1}{2}$ inches, the foundations of the piers consisted of 5 feet of masonry resting on wells 3 feet in diameter and 5 feet deep.

Plan annexed Marked G.

10. The bridge was opened for traffic on the 1st November 1871; on the 6th, 7th, and 8th of the same month a heavy flood came down the river, accompanied by a violent storm and a considerable rise of the sea, and the bridge was completely destroyed on the morning of the 8th, the first arch having given way at about 2 A.M.

11. Full particulars of the destruction of the bridge are given in the Superintending and Executive Engineers' letters, printed with O. G., No. 3,140 of the 13th December 1871, and No. 298 of 31st January 1872, copies of which are attached to this report.

Marked C. and D.

12. In accordance with the above orders a Committee was formed, consisting of Mr. Logan, Chief Engineer of the Great Southern of India Railway, Mr. Robinson, Acting Deputy Chief Engineer of the Madras Railway, and Captain J. Pennycuick, R. E., to investigate and report upon the causes of the destruction of the bridge.

13. The first point to which the attention of the Committee was directed was the manner in which the different piers and arches had fallen.

14. The first and second piers, counting from north to south, have fallen southwards, towards the right bank of the river; the remainder have all fallen northwards. The separation has in all of them taken place within 2 feet of the flooring level, and each of the fallen piers has separated in falling into three or more parts, the fractures in every case, with a single exception, having been horizontal.

15. The exception to this is in the case of the third pier from the north, the upstream portion of which, about half the length of the pier, and its whole height up to the springing of the arch, has separated by a vertical fracture from the remainder of the pier and fallen obliquely up-stream, towards the north-west.

16. The Superintending and Executive Engineers, depending on the reports of the subordinates on the spot, came to the conclusion that the pier which first gave way was the second from the south, and in his letter No. 870 of 25th December 1871 (paragraph 7), the latter officer explains what he considers to be the cause of the failure. In accordance with this opinion Government directed that preparations should be made, in the first instance, for the examination of the two southern piers only.

Printed with G. O., No. 298 of 31st January 1872.

17. The manner in which the piers had fallen led Captain Pennycuick (who had gone down to the site ten days before the other members of the Committee) to suppose that the arch which first fell was the third from the north, and that officer accordingly requested and obtained permission to examine the piers of this arch as well as the two previously mentioned.

18. With regard to the two latter, the most careful examination showed nothing wrong with either the foundations of the piers or the flooring of the bridge.

19. With regard to the third pier from the north, it was found that the up-stream end of the pier had sunk considerably, and that the down-stream end had been raised; this was proved by the fact that the combing of the pier was visible three inches above the level of the flooring; in fact, that the whole pier had been as it were moved on a pivot at about the centre of its length. The portion adjacent to the pier of the curtain wall and flooring of the next arch to the south had been destroyed, and so, as far as the Committee could judge, had that of the next arch to the north. All these facts point clearly to a failure of the foundation

of the up-stream end of the third pier ; but the extent of this failure could not be ascertained without a more complete examination than the Committee were able to make with the means at their disposal.

20. The Committee are unanimously of opinion that the immediate cause of the destruction of the bridge was the failure of the foundation of the third pier from the north on the up-stream side. The sinking of this pier caused the fall of the third arch, and the thrust of the arches overthrew the other piers in succession.

21. The failure of the foundation was probably caused by the scour produced by the contraction of the waterway, but as to its extent the Committee are not able to speak positively without a more thorough examination of the foundations than they have been able to make.

22. To examine the foundations completely it would have been necessary to make a regular coffer-dam round the third arch and its two piers, and to employ pumps for removing the water from the space enclosed, as it was found impossible to keep it down thoroughly with picottas and buckets. To carry this out would have been expensive, and have taken some time ; it would have involved a second time taking away the civil members of the Committee from duties from which they could ill be spared, and would have put back the examination to a dangerously late period of the season, the Superintending Engineer having stated that it should take place, if possible, not later than the end of February.

23. Moreover, the Committee are disposed to attach the less importance to the accurate settlement of this question, that they consider it to have been almost a matter of chance which pier or arch fell first, the bridge being doomed to destruction from the first by reason of its defective design.

24. The drainage area of the Vellaur at the site of the bridge is about 2,800 square miles. The total waterway of the bridge *up to the crown of the arches* was 11,056 square feet, or 3·95 square feet per square mile of drainage area. Up to the springing of the arches the waterway was only 2·39 square feet per square mile. The quantity of water to be passed through the bridge was also liable to be greatly increased by the tide water, which occasionally, as at the time when the bridge fell, is very considerable, and by the drainage of the large Veeranum and other tanks in the Chellumbrem taluq which are fed from the Coleroon. The bed of the river is loose sand.

25. Again, it appears from the correspondence* that in 1857 the width of the river at ordinary flood level (about 11 feet above the level of the flooring of the bridge) was 500 feet ; in 1862 it had increased to 666 feet, and in 1867 to 753 feet, showing that the natural bed of the river had not sufficient capacity to carry off heavy floods. This mode of relief was of course stopped by the construction of the bridge. No section of the river at the former periods can be found, but according to that dated July 1867 (Annexed marked E.) the area of the section up to ordinary flood level was 4,973 square feet, and up to 20 feet above the flooring of the bridge 12,924 square feet.

* Precis No. 16.

26. It seems impossible to ascertain, with any amount of accuracy, the amount of water brought down by the flood which destroyed the bridge, or the height to which it rose. As far as can be gathered from examination of the river

banks and questioning of the subordinates who were present at the time (whose answers appear very untrustworthy), the water must have been about 17 feet above the flooring of the bridge when the latter gave way, and have continued to rise for another foot, or perhaps a little more, afterwards. An attempt has been made to calculate the discharge from the levels at the Shateatope anicut, and though this can only be considered as a very rough approximation, it seems to show that the flood, though doubtless an unusual one, was not greater than should be expected and provided for in an Indian river. This calculation gives a mean velocity through the bridge of 1,153 feet per minute, without taking into consideration the tide-water or the drainage from the tanks on the south side of the river.

27. The flood appears to have been aided by an unusually high tide, but it is quite impossible to ascertain with any degree of accuracy to what height the latter really rose. There is, however, no doubt that it was unusually high, and added very seriously to the effect of the flood. Still, considering the position of the bridge, this was no more than was to be expected in the ordinary course of events, and should have been considered in the design.

28. The Committee, moreover, consider that not only was the waterway insufficient, but the foundation wells were not nearly deep enough, and that the arches were too light for the span.*

* Rankine's formula gives 2·76 feet as the least proper thickness for an arch of the dimensions of those under consideration; as built, the thickness was only 1·87 feet.

29. The earliest record which the Committee have been able to find deals with the design as already complete, so that there is nothing to show on what calculations the dimensions of the bridge were originally based; but in all the subsequent correspondence, notwithstanding the numerous revisions the plan and estimate have undergone, there is no single reference to the drainage area of the river, its discharge, or the area of waterway of the bridge. Mr. Norfor appears to have had some misgivings upon the subject, for we find that in 1867 he suggested the addition of two arches on the ground that the ends of the bridge "would be within the water-spread of even ordinary freshes." Colonel Foord, however, negatived this proposal on the somewhat doubtful ground that the river bed was considerably narrower 500 yards higher up, where the banks are steep on both sides; and the only alteration made was a slight addition to the height of the piers and rise of arches.

Precis of correspondence, No. 29—31.

30. With regard to the quality of the work it must be remembered that "good" and "bad" are altogether comparative terms, and can only be used with reference to the price paid, the object for which a work is intended, and the circumstances under which it is executed. In this case the masonry, though much better than the ordinary run of departmental work, was not nearly up to the standard that a Railway Company would require in a building of this nature; while the fact that the arches sank from 3 to $5\frac{1}{2}$ inches shows that the arch work was not of a quality suited to a work of such magnitude. Still, considering that the price paid for the masonry was only Rupees 4-3-6 per cubic yard, and that

Register of sinking arches annexed, marked F.

the superintendence was performed under the circumstances hereafter detailed, while a Railway Company would have had a competent Superintendent constantly on the spot and would have paid Rupees 7 or more to secure the best quality of masonry possible, it was decidedly as good as could be expected. Moreover, the Committee do not consider that even if the work had been of the highest quality possible, the bridge, designed as it was, would have stood any longer than it did.

31. The circumstances under which the work was executed require a little more attention.

32. It appears that when the work was first commenced in April 1869, Mr. Norfor was in charge of the 4th Range of the South Arcot District, in which the bridge is situated; the ordinary duties of this range are very heavy, as it is the one which contains the principal irrigation works of the district: in addition to the ordinary works of maintenance and repair, Mr. Norfor's duties included the construction of three anicuts with subsidiary works, and during the latter part of the year he was also employed in maturing an important irrigation project, the cost of which was eventually estimated at nearly Rupees 2,00,000.

33. The execution of this project was commenced during the following April, but Mr. Norfor was relieved from the greater part of the work entailed by it, by the appointment of an officer for its special charge in July. In October 1870 the charge of a second Range (No. 1) was added to his duties, the Range Officer having gone away on leave; in this range also were several important irrigation projects to be investigated and worked out, and for three months, in addition to the two ranges, Mr. Norfor had charge of the Superintending Engineer's office.

34. Mr. Norfor was in April 1871 permanently relieved of the charge of the 4th Range (having held it for six months in addition to the 1st and for three months with the Superintending Engineer's office as well), and posted to the 1st Range, retaining charge of the Vellaur bridge, which is situated twelve miles beyond its limits.

35. With regard to subordinates, it appears that the only subordinate employed on the bridge was the regular Overseer of the Chellumbrem Taluq (the richest and, consequently, the most troublesome in the district), and only during the last four months of the work, that is from August to October 1871, was this Overseer relieved of his other duties and placed in special charge of the Vellaur bridge. Indeed, from April to August 1871 he was not even under Mr. Norfor's orders, but under those of the officer in charge of the 4th Range.

36. Comment upon such a state of affairs seems superfluous; if every arch had fallen in the instant the centerings were removed no one could have been surprised, and the last person to be blamed would be the officer who was expected to work under such an extraordinary system. The fact that the work under the circumstances was as good as it has been found to be is, in the opinion of the Committee, highly creditable to Mr. Norfor.

37. The conclusions of the Committee may be summed up as follow :—That the bridge failed through faultiness of design and not *primarily* through any defect in material or workmanship. That the latter, though not of a quality suited for

so large a work, were considerably better than could reasonably be expected, considering the price paid and the circumstances under which the work was executed.

(Signed) D. LOGAN,
*Chief Engineer, G. S. I. Railway.*

(Signed) W. R. ROBINSON,
*Ag. Dy. Chief Engineer, Madras Railway.*

(Signed) J. PENNYCUICK, Captain, R.E.,
*Executive Engineer, P. W. D.*

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NOTE ON DISCHARGE OVER SHATEATOPE ANICUT.

THE Anicut bridge has nineteen segmental arches of 31 feet span and 7¾ feet rise, with piers 8 feet high. The anicut and surplus sluices which were open have 9 vents, each 17 feet × 6 feet, their centres being 6 inches below crest of anicut. The flood rose to a height of 13½ feet above crest, and the fall through the bridge *is stated* to have been 15 inches. Assuming 600 feet* per minute as the velocity of approach, we have—

| | |
|---|---|
| Head due to velocity of approach $(\frac{600}{400})^2 =$ | 2·25 |
| ,, on bridge ... ... ... ... | 1·25 |
| Total ... | 3·50 |

Velocity through bridge $= 400 \times \sqrt{3{\cdot}50} = 748{\cdot}32$ feet per minute.
Area of waterway occupied 7,420 square feet.
Discharge = 748 × 7,420 = 5,550,160 cubic feet per minute.
Head on sluices is 14 feet.
Velocity, $360\sqrt{14} = 1346{\cdot}76$ feet per minute.
Area = 9 × 17 × 6 = 918 square feet.
Discharge = 918 × 1347 = 1,236,546 cubic feet per minute.
Area of breaches in trunk road 10,400 square feet.
Velocity (say) 240* feet per minute.
Discharge 240 × 10,400 = 2,496,000 cubic feet per minute.

| | Cubic feet per minute. |
|---|---|
| Discharge through bridge ... ... ... ... ... ... | 5,550,160 |
| Sluices ... ... ... ... ... ... ... ... | 1,236,546 |
| Breaches ... ... ... ... ... ... ... ... | 2,496,000 |
| Total... | 9,282,706 |

The drainage area is about 2,650 square miles, and 1″ per hour from this area would give 102,608,000 cubic feet per minute. The calculated discharge (which is probably somewhat over estimated) amounts therefore to about ·09 inches per hour.

At the bridge the drainage area is 2,800 square miles, and the discharge would be increased to 9,808,142 cubic feet per minute. The flood is believed to have risen to about 17 feet above the flooring of the bridge before the latter gave way; at this level the area of waterway occupied was 8,509 square feet; so that the mean velocity through the bridge would be 1,153 feet per minute.

In addition to the natural drainage of the river, a considerable quantity of tide water must have had to pass through the bridge, which had also to carry the surplus from the Veeranum tank which is fed from the Coleroon, and of several other tanks in the Chellumbrum Taluq. It is also said that several tanks in the Trichinopoly District on the south bank of the river were breached.

* These velocities are probably over-estimated.

*Proceedings of the Madras Government, Public Works Department,*
*15th October* 1872.

## VELLAUR BRIDGE.

*Memorandum to accompany the Report of the Committee appointed to examine into the causes of the destruction of this bridge by D. Logan.*

In the interval between settling the draft of the report in question and its receipts and reperusal (within the last few days) for signature, a few remarks in amplification of the subject have occurred to me ; and as at this date it would entail undesirable delay in rendering the report to await the concurrence of the other members of the Committee to incorporating these remarks in the report itself, I make them the subject of this memorandum, for which, of course, I am alone responsible.

With reference to the faultiness of design in the bridge, I am of opinion that the chief fault lay in the shallowness of the foundations. In the sandy bed of a river subject to heavy and rapid floods, the foundations were carried only 10 feet below the bed of the river. The lower 5 feet of these foundations consisted of wells built of brick-in-mud. The wells were, as described to me by the Native Overseer who attended the Committee at the site of the bridge, filled with concrete, in the following manner :—A basket full of broken brick and another filled with lime and sand were held opposite and close to each other over the open well full of water into which the contents of the baskets, made to intermingle as they fell, were then poured. If this is a correct description of the mode of laying in the filling of the wells, it is scarcely possible that any cohesion existed in the filling, which it was an object to make into a solid mass.

Had the foundations of the bridge been carried down about 20 feet below the bed of the river with wells properly constructed, I believe that, in spite of insufficient waterway and other defects, the bridge would have withstood the flood which destroyed it.

In support of the opinion that the foundations were too shallow, I may point to the fact that I found a large hole scoured out of the bed of the river (immediately below the bridge and near the south bank of the river) to a depth of 17 feet below the flooring, or 7 feet below the lowest part of the foundations.

With regard to the quality of the brick-work, I believe that its unequal character was due to the want of the close supervision of an Engineer Officer rather than to the lowness of the price allowed. No doubt a price for work, out of which there is little or no profit to be honestly gained by suppliers of material and labour, holds out a premiumfor roguery, yet without close and conscientious supervision, in my experience, the price may be one out of which a large percentage may be profit, and the work will be utterly bad.

In making these remarks I would guard against its being supposed that I am blaming the Executive Engineer, in the present case, for want of supervision, which, under the circumstances detailed in the Committee's report, it was impossible for *him* to afford. I am speaking of the system and of the work as it was opened up to me, as it never could have been to the Executive Engineer, the fallen piers and broken arches laid bare more than could have been seen on occasional visits of inspection, however conscientious, during construction, and it seemed probable to me that the unequal quality of the work pointed out, the better kind when the Engineer had been expected, and the worse the time of his departure and absence.

There was evidence in this way that some one *on* the work knew what good work is, the Maistry or Overseer, or both, for some of the brick-work exposed was fairly good, while other parts were so bad that I was able to pull out by hand the bricks from what called chunam was in reality little more than sand. Again, on the north bank of the river a full-sized diagram of one of the arches was laid out on the ground in chunam, showing all the bricks and joints distinctly laid in a workmanlike manner ; and had the arches been built throughout according to this pattern, no better work, with the materials available, could have been executed.

I am quite confident that, on every work of the magnitude and importance of the Vellaur bridge, it would be a measure of real economy to appoint an Engineer to be resident on the work, or at all events to be able to inspect the work thoroughly every two or three days. In no other way, in my opinion, can sound and really *good* masonry be ensured in this country.

Such a system would give a real instead of a nominal supervision, and would at the same time bring prices for work and material into a natural and healthy condition ; for all chance of profit through dishonest work being at an end, no contractor would be found to take work except at fairly remunerative prices, and in this way Government would not only come to realize the cost of honest and sound work, but one strong motive for dishonesty would be removed from contractors and others engaged and associated with them.

CAMP AT DINDIGUL,
24*th June* 1872.

(Signed) D. LOGAN,
*Chief Engineer, G. S. I. R.*

*Memorandum to accompany Vellaur Bridge Report.*

THERE are many opinions expressed in the report with which I do not agree, but I pass them over, as Mr. Logan's memorandum, every word of which has my entire concurrence, explains fully the cause of the failure of the bridge. One remark, however, is made in paragraph 30 that demands notice, it is there stated that "good and bad are altogether comparative terms and can only be used with reference to the price paid, the object for which a work is intended, and the circumstances under which it is executed."

2. To works of different magnitudes, different classes of masonry are suitable, but goodness and badness are inherent qualities and do not depend on extraneous circumstances.

MADRAS,
25*th July* 1872.

(Signed) W. R. ROBINSON,
*Acting Dy. Chief Engineer, M. R.*

No. 263. From the Superintending Engineer, 5th Division, to the Secretary to Government, Public Works Department, dated Camp at Salem, 21st August 1872, No. 100.

I HAVE the honour to return the Committee's report and other enclosures in your letter of the 10th August, No. 107, with the following observations on the construction and fall of the Vellaur bridge.

2 Plans.
8 Reports.

2. The plans and estimates for the four bridges across the Pooniar, Paravanar, Vellaur, and Coleroon, on the coast road, in the South Arcot District, were prepared by the late Colonel Lawford at the time he had charge of a portion of the South Arcot District in addition to Tanjore and Trichinopoly. The bridges across the Pooniar and Paravanar were commenced in 1855 and completed in 1857, while I was District Engineer of South Arcot. The Coleroon bridge was built at the same time by the Public Works Department of Tanjore. The waterway allowed for these bridges has proved to be quite sufficient, and they have not, up to this time, sustained any damage from floods. The bridge across the Vellaur was not commenced till May 1857, but nothing was done that year, except collecting some materials, as the mutiny put a stop to that and all other new works.

3. The bridge, as originally designed, consisted of ten arches of 50 feet span on piers 8 feet high. There were to be no wells in the foundation, as it had been assumed that the bed of the river was firm clay. When I ascertained that the bed of the river was only sand, I prepared fresh plans and estimates, first for a bridge of eleven arches of 45 feet, and afterwards for a bridge of nine arches of 55 feet with foundations on wells. The former was the design adopted in 1869

with some additional height to the piers. There was also prepared, at the suggestion of the late Colonel Ouchterloney, a plan and estimate for an iron-screw pile bridge, as one of the works to be undertaken by a Land and Building Company that he was trying to get up. I also wrote to a Calcutta Firm for an estimate for a screw pile bridge; but the price for which they undertook to erect a bridge of that kind was more than double the estimate for a brick bridge; as there were no facilities for constructing an iron bridge in the district, I gave up the idea of having one.

4. The building of the masonry bridge was commenced in April 1869. In that year the two abutments were built, also the two piers at the south end with their floorings and retaining walls. By September the allotment of funds was expended, and no more work could be done till the next official year. I saw the well sinking at the south abutment in progress, and I saw the work again in January 1870. In April I gave over charge of the division and was absent on furlough for two years. The work was resumed in April 1870, and, during the next twelve months, four piers at the north end were built with their floorings and retaining walls. Thus at the expiration of two years from the commencement of the bridge, there remained to be built four piers from their foundation with floorings and retaining walls.

5. This being the case, when work was resumed in April 1871, it would have been more judicious, considering that the best part of the working season was over, to have confined the operations of the year to the completion of the piers and abutments and the preparation of materials for arches and centrings, leaving the arches to be turned in the first three months of 1872, the only months of the year in which, as a rule, the river is free from freshes; all the brick-work of the piers and abutments would then have been thoroughly dry. Even those built in 1869 were raised a foot and a half at the least. Instead of this the building of some of the piers from their very foundation and the turning of the arches were going on at the same time, and by the middle of August the last arch was completed.

6. The Committee are of opinion that the immediate cause of the destruction of the bridge was the failure of the foundation of the third pier from the north end, but do not attach much importance to the settlement of the question, which pier first gave way. I submit, however, that it is a matter of very great importance; for, if the failure of the bridge is due to inadequate foundation and contraction of waterway, the portion of the bridge that might have been expected to be the first to give way would be one of the two piers at the south end, as the stream sets so strongly against the south bank of the river. The Committee, however, report that the most careful examination showed nothing wrong with the foundation or flooring of the two southern piers. The deep hole below this part of the bridge, mentioned in a separate memorandum, may have been scoured out after the fall of the bridge.

7. The Committee remark on the low rate allowed for the brick-work and the inadequate thickness of the arches. The rates in the estimate were those which had been proved to be sufficient, and during the progress of the work supplemental estimates were submitted and sanctioned. High rates alone do not secure good work; the best works in the district have been the cheapest, the goodness and the cheapness being due to the same cause, namely, continuous good superin-

tendence. The depth of the arches at the crown 1 foot 10½ inches, or two and a half bricks, is that which has always been given in the district to arches of forty-five span. I may mention that as regards thickness of piers span rise and thickness of arches the Vellaur bridge was an exact copy of the Pooniar bridge at Cuddalore, built fifteen years ago.

8. The foundations of the Vellaur bridge, according to the estimate and specification, were to be 10 feet deep, of which 5 feet were to be of solid masonry and 5 feet of brick-in-chunam wells. The wells were to be filled in either with brick cubes or with concrete. There were to be floorings one and a half feet thick between the piers with retaining walls above and below built like the foundations of the piers, that is 5 feet of wall on 5 feet of brick in chunam wells. The foundation was to be 10 feet below the lowest part of the bed of the river, or about 15 below for more than half the breadth of the river. There is no bridge, anicut or other river work in the district which has deeper foundations where the bed of the river consists, as in this case, of loose sand. If any of the wells were not filled with concrete or with brick cubes, then the work was not in accordance with the estimate and specification.

9. The waterway allowed for the bridge was in accordance with the section of the river at the time the original design was made. Since then, from the stream setting strongly against the south bank, the deep bed of the river has been moving year by year more to the south, and the breadth of the river at the site of the bridge has been increasing, but I did not consider that any reason for increasing the waterway of the bridge. It is true that the Executive Engineer once suggested that the bridge should have two more arches; but on my asking him to examine the river above the site of the bridge, he wrote to me and expressed himself perfectly satisfied with the waterway determined on. It is mentioned in Appendix A that the breadth of the river 500 yards above the site of the bridge where the bank is high on both sides is 452 feet, while the clear waterway of the bridge is 495 feet, and the distance between the abutments is 555 feet.

10. I have known several instances of a needlessly large bridge having been designed, from taking the breadth of the river at only one place as a guide for the length of the bridge. The bridge designed by the Road Department and sanctioned by Government, for the Pooniar, on the Trichinopoly road, was to have forty-five arches of 45 feet span on piers 11 feet high, while the bridge actually built over the same river at Cuddalore, twenty-five miles lower down, has only nineteen arches of 45 feet on piers 6 feet high. The bridge sanctioned for the Mullataur on the Trichinopoly road was to cost 42,000 Rupees, but the bridge I built seven years ago cost, with its long gravelled embankment, only 6,000 Rupees.

11. I attribute the fall of the Vellaur bridge to its having been exposed to an extraordinarily high flood immediately after its completion and before all the brick-work was thoroughly dry. I believe there was sufficient waterway, and after the construction of groynes on the south bank the cross section of the river would have been improved and the capacity of the bridge increased. This is the only case of the total failure of a large new work in the South Arcot District during the last seventeen years; the other large bridges and anicuts having been completed without any accident during the progress of the work.

*Proceedings of the Madras Government, Public Works Department,*
*15th October* 1872.

No. 263A. *Memorandum by the Chief Engineer of the Public Works Department.*

The Vellaur Bridge Committee state that "the bridge failed through faultiness of design and not *primarily* through any defect in material or workmanship."

2. The Superintending Engineer who designed the bridge "attributes its fall to its having been exposed to an extraordinarily high flood immediately after its completion, and before all the brickwork was thoroughly dry."

3. The theoretical grounds on which the former base their opinion are—

*1stly.*—The insufficiency of waterway with reference to the drainage area. The latter being taken at 2,800 square miles, the waterway up to the crown of the arches is 3·95 square feet per square mile, and up to their springing 2·39 square feet, provision having also to be made for tide-water and surplus of tanks fed from the Coleroon.

*2ndly.*—The insufficiency of waterway with reference to the width of the river, 495 feet clear of piers being allowed to a section at ordinary high flood level stated to have been 666 feet in 1862 and 753 in 1869, or natural water section of 4,973 square feet at ordinary high level calculated at 15·3 above the flooring level, and 8,509 square feet at the level attained when the bridge gave way, as against 6,682 square feet provided up to springing of arches, and 11,056 square feet up to their crowns. The flood level when the bridge fell being estimated at 17 feet above flooring level, and a foot or more afterwards.

*3rdly.*—Insufficiency of depth of foundation wells.

*4thly.*—Insufficient thickness of arches.

4. The actual facts which the Committee report with reference to the bridge are that the up-stream end of the third pier from the north side built in 1870-71, had sunk considerably and that the down end had been raised; the combing of the pier being visible 3 inches above the floor level, and portion of the curtain wall and flooring of the arches on both sides being destroyed. Half the length of this pier, for its whole height, was separated vertically from the remainder of the pier, and had fallen obliquely up-stream to the north-west. Of the other piers the first and second from the north side had fallen southwards, and every other pier northwards. The separation in all but the third pier had taken place within 2 feet of the floor level and each had separated into three or more parts, the fractures having been horizontal.

5. These facts can lead to no other conclusion but that arrived at by the Committee in their 20th paragraph, namely, that the immediate cause of the destruction of the bridge was the undermining of the third pier from the north on the up-stream side. Its sinking caused the fall of the third arch (not the second the up-stream half falling towards the north side), and the thrust of the arches overthrew the other piers in succession. No further examination of piers was required; the third pier was accurately detected as the faulty one to be examined; while the hear-say evidence which led to the examination of the two southernmost piers, namely, "that the second arch from the south was *heard* to fall with a crash, at about 2 A.M., on the morning of the 8th November 1871," was ludicrously defective. The Superintending Engineer's theory, that the pier that might have been expected to give way was one of the two southernmost, must

yield before the established fact that it was the third pier from the north, the foundations of which were undermined; the point to which he rightly attaches great importance has undoubtedly been settled.

6. The accuracy with which the particular manner of failure has been settled, leaves also no doubt but that the Committee are justified in attributing it to defective design. The only remaining question is in what was the design defective; and the only defect conclusively established by the facts reported by the Committee is that of insufficient depth of foundation wells. What further defects there were is matter of conjectural opinion.

7. My own is that Colonel Foord's design was a bold one having reference to the drainage area above and river section, but warranted by the experiences of the last seventeen years, detailed in paragraphs 8, 9, 10 and 11 of his report. Had he been bolder, and omitted the flooring and wells between arches so as to allow of an even scour through them all, I consider it possible that his bridge might have stood; and that it certainly would if besides such omission the pier foundations had been laid 10 feet deeper. The state of a river-bed composed of pure sand, after subsidence of floods, gives no clue whatever to what might have been its state during the prevalence of floods. The deep pool on the south side, and general deepening of the rest of the bed, shown in the section taken in January 1872, at a point 93 feet below the bridge site, are probably due to the overfall of the water from its ruins acting with most force where the dry weather set of the stream occurs. During the high flood, as the facts show, the action was strongest and deepest near the north side; and this is probably due to wash caused by recession of tidal water in the next lower bend of the river along the north bank. The action of the tide I hold to have been detrimental only when receding, and have no doubt but that it was during its ebb that the failure occurred, if the hour has been correctly reported; for during its flow it would undoubtedly counteract undermining action of the river current. No extra provision of water-way was needed for surplus of tanks supplied from the Coleroon, as arrangements are doubtless always made for shutting off the extra supply of water on such occasions.

8. The thickness of arch used is practically demonstrated by Colonel Foord to have been sufficient for a well built bridge designed to bear the ordinary weights of Indian road traffic, though insufficient for railway purposes.

9. The Committee having satisfied themselves as to the cause of the failure of the bridge, and that it was *not* owing to defect in material or workmanship, I do not feel at liberty to follow them in their comments on rates and supervision, which are evidently beside the mark in this instance.

(Signed) G. W. WALKER, Colonel, R.E.,
*Chief Engineer, D.P.W.*

*19th September* 1872.

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No. 264. ORDER THEREON, 15th October 1872, No. 2,427.

CIVIL WORKS, No. 10.

ORDERED that the Report of the Committee on the Vellaur bridge, the letter from the Superintending Engineer of the 5th Division, and the Memorandum from the Chief Engineer, Public

Works Department, be communicated to the Government of India in continuation of letter No. 146 of 17th January 1872.

2. The Governor in Council offers his best acknowledgments to the gentlemen composing the Committee for their lucid exposition of such facts connected with the bridge as could throw light on the cause of its fall. He accepts their conclusion generally, namely, that the cause of failure was defect of design and not of material or workmanship. He admits at the same time that the Superintending Engineer's former experience justified his belief in the sufficiency of his design, except as to depth of foundation of the piers; and he is glad to find that the Executive Engineer Mr. Norfor is in no way to blame for the destruction of the bridge, having done all that lay in his power to ensure its proper construction.

3. The attention of all Superintending Engineers and Range Officers will be called to former Government Orders prescribing the submission of detailed reports as to drainage area, rainfall, fall of river, etc., with accurate cross sections and borings at the site, to accompany all plans and estimates for bridges of any importance. The amount of superintendence required and available should also be matter of special report.

4. A plan with estimate of Rupees 70,000 (not including abutments or carriage of materials from Madras) prepared by the Superintendent of the Government Workshop for a bridge of twelve iron girder spans of 50 feet each on screw pile piers will be forwarded to the Superintending Engineer of the 5th Division for consideration of the Local Fund Board; together with similar papers sent in by Mr. DeClosets for a bridge of five cast-iron arches of 100 feet each, on masonry piers, to cost from Rupees 96,000 to Rupees 1,20,000.

5. His Excellency the Governor in Council regrets that he cannot consider as satisfactory the explanation given by Captain Pennycuick of the very great delay that has occurred in submission of the Report of the Committee of which he was a member. The draft appears to have been made out on the 6th March (four days after the Committee sat) and returned to him by the beginning of April; but not to have been fair copied for two months, or finally received in the Government Office till the end of July. Any difficulty in having it transcribed would have been obviated had he simply represented his need of assistance and sent the original draft to be copied in the Secretariat Office.

(Here enter No. 2,428, dated 15th October 1872.)

(True Extract.)

Colonel, R.E.,
*Secretary to Government.*

To the Committee for the Examination of the Vellaur Bridge.
To Superintending Engineers.
,, Major R. B. Kennedy.
To the Financial Department.

Exd. E. C. Shunker.

Govt. of {1872} Ma

PUBLIC WORKS

*To*

THE COMMITTEE FOR THE EXAMI

OF THE VELLAUR BRI

&c., &c.,

*Dated October 15th.*

*Recd.*

*G. O., 15th October* 1872, *No.* 2,427.

**OCTOBER.**

**Nos. 261-264**

*Vellaur Bridge, South Arcot District.*—Passing orders on papers relating to the failure of the Vellaur bridge in November 1871.

Public Works Department,
Ootacamund, 15*th October* 1872.

No. 265.

No. 2,428.

To

The SECRETARY to the GOVERNMENT of INDIA,
Public Works Department.

CIVIL WORKS, No. 11.

Sir,—I am directed, in continuation of Colonel Carpendale's letter No. 146 of 17th January last, to communicate, for the information of the Government of India, the Report of the Committee on the Vellaur bridge, an explanatory letter from the Superintending Engineer of the 5th Division, and a Memorandum by the Chief Engineer of the Public Works Department.

2. The destruction of the bridge is attributed by the Committee to the insufficient depth of the foundations. Inadequacy of waterway was also a material defect in the design of the work; but two of the Members of the Committee have recorded their opinion that the bridge would nevertheless have withstood the severe floods to which it was exposed so immediately after its completion if the foundations had been carried 20 feet, instead of only 10 feet, below the bed of the river. The materials and workmanship are described by the Committee as "much better than the ordinary run of departmental work," though much inferior to the standard required by Railway Companies, and as good as could be expected, considering the price paid and the supervision exercised. The Committee further comment on the inadequacy of the superintendence during the construction of the work.

3. I am to state that the Governor in Council accepts the conclusion of the Committee as to the cause of the accident. For the prominent errors in the design, insufficiency of foundation and inadequacy of waterway, the Superintending Engineer is answerable; but in his defence, it must be considered, as urged by him, that no other work in the district in loose sand has deeper foundations, and that the waterway was sufficient according to his calculations and experience. Several other bridges have been built in similar fashion on the same line of road and have stood well. Under these circumstances, the Governor in Council is not prepared to attach blame to Colonel Foord for the loss of this bridge, much as it is to be regretted. Care will be taken in future to guard against the errors committed in this case. It is clear that no blame attaches to the Executive Engineer, Mr. Norfor, it being admitted that so far as material, etc., are concerned, the bridge was substantially constructed under considerable difficulties.

4. As regards the amount of supervision available, the Government need hardly point out the impossibility of supplying as much agency of this character as the Committee deem necessary. The Public Works Establishment of the Presidency is far too limited in numbers; the area of country over which it has to operate is too large; the number of works entrusted to it is too great to admit of

special officers being spared for any but the most important works. In the present case the objection of the Committee is practically of no great weight, for it is admitted that the work was sufficiently well performed, the defect being in the design, not in the construction. It would certainly be very satisfactory to the Government if they could afford to employ the extensive agency and pay the high rates which Railway Companies do; but this is beyond their means, and so long as the work performed for Government is, as in this case, good enough for its purpose, it would be a waste of public money to strive for more. A bridge, of which it can be truly said, that if its foundations had not yielded, it would, notwithstanding deficient waterway, have stood an extraordinary flood within a few days of its completion, is certainly built well enough for every practical purpose, and the Government with its limited funds and agency would hardly be justified in aiming at more. Under the new organization, it will, it is hoped, be in the power of Government to provide special agency to a greater extent than has hitherto been the case; but officers in the position of Railway Engineers with extensive agency and ample funds have a very imperfect idea of the difficulties with which the Engineer Officers of Government have to contend.

I have the honour to be,

Sir,

Your most obedient servant,

Colonel, R.E.,

*Secretary to Government.*

Exd. E. C. Shunker.

Public Works Workshops Department
No. 102
Chepauk 17th April 1872.

From

The General Superintendent
Public Works Workshops and Stores

To

The Secretary to Government
Public Works Department
Fort Saint George

Sir,

I have the honor to forward herewith the Plans and Estimate amounting to Rupees 69,362-12-0 of the Iron Girder Bridge for the Vellaur River, asked for in G.O. of the 13th December 1871 No. 3140. I have not yet received the report on the condition of the old Masonry Piers but from the drawing of the late Bridge, sent me by the Range Officer I do not think it would be safe to again employ them as the foundations are only 8 feet deep in sand below the floor. The Bridge is in 12 spans of 50 feet each and supposed to cross the river near Muttore at the present crossing vide Section No. II Enclosed - but this will rest with the Superintending Engineer who will also decide whether the Bridge should be shorter or longer.

I have the honor to be
Sir
Your most Obedt Servant

J. J. Granger
Genl Supt P.W. Workshops & Stores

Enclosures Four
1 Plan
1 Section
1 Estimate
1 Specification

Reo 15 December /71 Nos 227–229

P. W. 1872 Depart-
ment

No. 1909.

The General Superintendt
P. W. Workshop & Stores

To
The Secretary to Governmt
Public Works Dept.
Fort St George.

Dated 17th April 1872
Recd 17th

No. 102 G.W.

Enclosures. Four

Forwards Plan and
Estimate amounting to
Rupees 69,362–12–0 of
the Iron Girder Bridge
for the Vellaur River.

Keep till Report
comes – G.W.

From:

A. deClosets C.E.

Napier Foundry,

Madras, 24 May 1872.

To

Colonel Walker R.E.

Secretary to Government

D. P. W.

Fort St George:

Sir:

I have the honor to lay down for your consideration a plan for a bridge of cast-iron, with the view of offering to construct it should Government consider my proposition as acceptable.

I have the honor
to be
Sir:
your Obedient,

A. deClosets C.E.

From:
[illegible] de Vaart C.E.

24 May

to

Colonel Walker K.C.
Secretary to Govern[illegible]
B. M.
Fort St George

Sir:

I have the honour to [illegible]
Governor for approval [illegible]
a Plan for [illegible]
[illegible] with the [illegible]
of [illegible] to construct [illegible]
Should Government [illegible]
any [illegible]

I have the honour
to be, Sir
your Obedient [illegible]
[illegible]

P. W. [illegible] Depart:

No. 2621.

From:

A. Deblaut C. E.

Dated 24" } May/72
Recd/27" }

Enc: 1.

Submitting a Plan for a cast iron bridge over the Vellaur river -

*Proceedings of the Madras Government, Public Works Department,*
*13th December* 1871.

Read the following letters :—

No. 227. From the Acting Superintending Engineer, 5th Division, to the Secretary to Government, Public Works Department, dated Cuddalore, 16th November 1871, No. 181.

It is with great regret that I write to inform you of the total destruction, on the night of the 7th instant, of the new bridge across the Vellaur at Mutlur.

2. What I now communicate is taken from a demi-official letter from Mr. R. E. Norfor, who superintended the construction of the bridge, and who is, as you may imagine, deeply distressed by this most unexpected calamity; further particulars I will report when I have myself visited the locality, which I purpose doing in company with Mr. Norfor; at present the river is impassable for boats, the road leading to the bridge from the north is breached, rendering access from that side impracticable, and we are in the midst of a monsoon the like of which has not been known for twenty years, and of the abatement of which there seems no speedy prospect.

3. The particulars I have to communicate are briefly as follow :—On the night of the 6th a violent hurricane set in, and the river came down in very heavy flood (12 feet above the flooring of the bridge), to this—itself no ordinary trial to a bridge lately completed (the last arch was turned in September last)—was added the violence of the waves raised by the furious wind which beat against the down-stream side of the bridge, the whole forming as severe a trial as could well be brought to bear on a work.

4. The sea is said to have been raised several feet, and to have washed over the bridge. The second arch from the south bank appears to have first given way, the rest following one after the other.

5. It would perhaps be premature to here enter on the cause of failure; but this I may say that I feel convinced it is not due to either bad material, bad workmanship, or want of careful and experienced supervision. I myself examined, so far as I could examine, the bridge on 29th August, immediately after I joined the district, and I then thought, and still think, I had never seen a better piece of work, materials and workmanship being alike excellent; such was also the opinion of the late Colonel Boileau. A good Overseer had special charge of the construction, and the work was very frequently visited by Mr. Norfor, who commenced and completed it.

6. The destruction of this bridge, situated as it is on a most important line of communication, interrupted by a river so formidable as the Vellaur, cannot but be regarded as a serious disaster; but in these days of failures through the use of bad material, or the want or laxity of supervision, I trust it will be some little consolation to the Government to be assured that here these causes of failure are entirely wanting, and that all was done that could be done to bring this work to a successful issue, and to make it a credit to the department.

7. My opinion is that a masonry bridge in such a locality is a mistake, and that there should be an iron girder bridge on screw pile piers, or something similar thereto.

8. I will conclude by mentioning that I have just heard the water rose on the occasion alluded to 13 *feet* over the Vellaur Anicut at Shatiatope, and that, but for the breaching of embankments above, the bridge over that anicut would also have gone.

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No. 228. From the same Officer, dated Cuddalore, 20th November 1871, No. 185.

IN continuation of my letter No. 181, of 16th instant, I have the honour to forward a copy of Mr. R. E. Norfor's official report of the destruction of the Vellaur bridge.

1 copy of Report.

2. From this it will be seen that the flood rose, according to Mr. Norfor's calculation, to a height of 17 to 18 feet, and according to the Maistry in charge of the bridge to 19½ feet.

Whichever of these calculations is correct, it seems beyond doubt that the flood is 2 feet higher than any previously registered.

3. I have heard reports that some of the arches were blocked up by trees brought down by the floods, and, if so, some or other of the piers must have been exposed to violent shocks from trees dashed against them; these are dangers to which a masonry bridge is particularly liable, and which it is impossible to guard against; moreover, the smaller the space of the arches, and hence the greater the number of piers, the greater the danger, and thus only confirms me in my opinion that in such a site a masonry bridge is totally inapplicable.

4. It will be quite impracticable to make any examination of foundations before the month of January, and even then the only use of an examination will be to satisfy oneself as to how far such a flood acted on the foundations of known depth; if these are found not to have suffered, it will be an additional proof of the goodness of the work, but nothing more.

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From R. E. NORFOR, Esq., Executive Engineer, No. 1 Range, South Arcot, to the Superintending Engineer, 5th Division, dated Camp at Punrooty, 15th November 1871, No. 737.

YOU will doubtless ere this have received my demi-official letter of the 10th instant, reporting to you the unforeseen and lamentable destruction of the bridge across the river Vellaur at Mutlur. I intended to defer reporting the matter in official form in the hopes that I should have had an opportunity of examining the work so as to ascertain, if possible, cause of the accident; but as the river still continues to be in flood such an examination it is impossible to make at present.

1 Letter of Mr. Theodore.
1 Do. of Valoomyloo Moodelliar.

2. I received intimation of the destruction of the bridge on the evening of the 9th, I proceeded to Mutlur at once, and with great difficulty (owing to flooded state of the country and breaches across the road) reached the river on the morning of the 10th; there was nothing to see but the abutments on either bank, the river was running at a depth of 13 feet over the flooring of the bridge at the time, and the ruins were submerged.

3. From inquiries instituted I have been able to obtain the following information. On the night of the 6th instant this district was visited with a very severe hurricane (some call it a cyclone) accompanied with heavy rain; this continued till the noon of the 7th, the depth of water over the flooring of the bridge during the continuance of the storm is said to have been 12 *feet*,

and the river at the time, from the violence of the wind, had a regular sea on; the traffic over the bridge was stopped by the Maistry; in fact there were no carts, he says, owing to the state of the weather and the condition of the roads on either side; the river continued to rise steadily from morning of 7th, flooded the work-sheds, store-sheds, etc., on both banks immediately above the bridge, and rose up to the step of the bridge bungalow on the south bank. I calculate there must have been from 17 to 18 feet of water over the flooring of the bridge (although the Overseer gives it 19½ feet) when the accident occurred, which took place on the night of the 7th, or rather about 2 A.M. on the morning of the 8th. The second arch from the south abutment was first heard to fall with a crash, and all the others followed in succession at short intervals, and in the course of an hour they had all fallen in.

4. The arch that first gave away was the last but one uncentred on the 21st August (the last arch of all was uncentred on the 25th August), and it was not till two months and 10 days afterwards (on the 1st November) that I allowed carts to pass over the bridge, the traffic at this season of the year being very light owing to the almost impassable condition of the coast road between Cuddalore and Tranquebar.

5. I was at the bridge on the 27th, 28th, and 31st of October and 1st November, and on these two occasions I *thoroughly* examined the whole work, and the absence of any flood at the time enabled me to do so most effectually. I was perfectly satisfied that its condition was faultless.

6. It is my firm belief that this unfortunate accident would not have occurred if the bridge had had a chance of tiding over its first season with only ordinary floods. I have already reported to you numbers of such floods, 10 and 12 feet deep, passed under the bridge during September and October without causing the *slightest* damage of any sort; but the extraordinary flood which came down on this occasion has no precedent; the accompanying copy of a letter, from the Vellaur Anicut Overseer to the Talook Overseer, shows that notwithstanding the anicut shutters and surplus sluice being opened and the Trunk Road being breached, thus relieving the anicut of an immense volume of water, the depth of water running over its crest was 13½ feet, 11½ to 12 being the highest known without breaches in the Trunk Road forming the approach to the bridge over the anicut. This anicut is situated, as you know, from 10 to 12 miles above the Mutlur bridge, and it is possible that the suddenness with which the river came down, rising 13½ feet in the course of eight hours between 9 A.M and 5 P.M. on the 7th, caused the arch to give way under the vibration on the piers, and the work was doubtless too new and unseasoned to stand the shock of such a flood. As I have said I have not yet been able to examine the work, but I feel so sure of the excellent quality of the work done that I am sanguine there is no defect in construction.

7. It is a matter to be regretted that one or two abutment piers were not provided in this work, as there would then have been a chance of some of the arches being saved; but piers 13½ feet high and 6 feet in thickness, with a lateral pressure of a 45 feet arch, cannot be expected to stand in such a situation with the strong current there was at the time.

8. The interest I have always felt in this work makes me feel acutely the sad accident it is my faithful duty now to report upon. I have always endeavoured, during its construction, to give as much of my attention to it as I possibly could, though I must admit that I was not satisfied with the arrangement of the supervising staff, often finding it necessary for days together to entrust the work to a temporary Maistry on 20 Rupees a month. I myself had, in addition to the ordinary duties of the 4th Range, which are as you may know very heavy, the Mahmatoor, Katoomyloor, and Pelandoria Anicuts, to see to. I had also for the greater part of the time two ranges in my charge, and, for about three months, the charge of the Superintending Engineer's Office in addition to all this. I had no extra Overseer allowed me for this or any other work, though the bridge was a very difficult work to do, owing to its situation; the consequence was, as I have said, the Talook Overseer had other work to do as well as this bridge, which took him away for a week or ten days at a time, and it often happened that the Maistry was left alone; for all this I have every reason to believe that all did their work conscientiously and fearfully, and I do *not* think that any bad work has been done when my back was turned. Colonel Roberts inspected the bridge while it was in progress, and has reported the excellence of the quality of the work; the late Colonel Boileau more

than once inspected the work while in progress, and each time very carefully examined it; he was present at the uncentring of one or two of the arches, and, I believe, he too has reported very favourably on the quality of the work; and, if I am not mistaken, I think you yourself saw the bridge before the roadway was put on and while the arches were exposed.

9. The arches were perfect in symmetry; when uncentred the average sinking at the crown was 4 inches, *i. e.*, from 3 to 5 inches; the greater number sunk only $3\frac{1}{2}$ inches, and no signs of the *smallest appearance of a crack in any one of them*; in fact, I did not anticipate such success in the construction of the arches with the working staff at my disposal.

10. I will report further after the freshes have subsided sufficiently to allow of the work being examined properly, and will be glad if you can be present also at that time.

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No. 229. ORDER THEREON, 13th December 1871, No. 3,140.

CIVIL WORKS, No. 15.

THE Government have received with great regret the above reports of the total destruction of the bridge over the Vellaur in South Arcot, the main body of which had only just been completed. It is observed that in the papers which are before the Government there is nothing to show what was the immediate cause of the failure of the structure, and it is only even inferentially to be gathered that the whole of the piers have fallen, while it is entirely a matter of doubt whether they were overthrown by the thrust of the arches, and, if so, at what height, or whether their foundations were undermined. The Government consider it is necessary in the public interests that there should be a searching inquiry into the circumstances attending the failure of this bridge, and will appoint a special Committee to conduct it. The Superintending Engineer will immediately report about what time the water may be expected to have subsided sufficiently to admit of a thorough examination being made of the foundations of the structure, and whether any special appliances, such as pumps, will be necessary, and he will communicate any further information which may have reached him in regard to the fall of the first arch.

2. All necessary particulars relating to the site should be communicated to the General Superintendent of the Public Works Workshops to enable him to prepare drawings and an estimate for an iron girder bridge on screw piles in place of the masonry one, or on masonry piers raised on the old foundations if the latter are considered to be available.

(True Extract.)

(Signed) J. CARPENDALE, Colonel, R.E.,
*Secretary to Government.*

To the Superintending Engineer, 5th Division.
,, General Superintendent of Public Works Stores and Workshops.

Exd. S. T. Augustin.

Govt. of {1871} Madras.

## PUBLIC WORKS.

*To*

THE SUPERINTENDING ENGINEER,

5TH DIVISION.

&c., &c., &c.

P.W. 3/5-?/72.
410 ?

*Dated December 13th,*

*Recd.* *Encl.*

*G. O., 13th December 1871, No.* 3,140.

**DECEMBER**
**Nos. 227-229**

*Bridge across the Vellaur, South Arcot District.*—Passing orders on letters from the Superintending Engineer of the 5th Division, reporting the destruction of the bridge across the Vellaur.

*Proceedings of the Madras Government, Public Works Department,*
*31st January* 1872.

Read the following papers:—

No. 612. From the Acting Superintending Engineer, 5th Division, to the Secretary to Government, Public Works Department, dated Salem, 8th January 1872, No. 213.

WITH reference to G. O., No. 3,140 of 13th December 1871, I have the honour to forward a copy of a letter from the Executive Engineer, Cuddalore, giving additional information regarding the Vellaur bridge recently destroyed.

2. The examination of the foundations should be made between 15th January and the end of February and not later than the latter date.

3. No pumps or other special appliances were used in the construction of the bridge, and Mr. Norfor is of opinion that the necessary examination of the foundations may be made with the aid of picottahs.

4. In the G. O. above quoted, reference is made to apparent omissions in the reports forwarded to them; it seems therefore only necessary to mention that when these reports were written the depth of water was far too great to admit of it being ascertained what portion of the piers had been carried away, nothing being visible but part of the abutments, while any examination of the foundations was, of course, out of the question.

5. There can be no reasonable doubt that the destruction of the bridge is due directly or indirectly to the unprecedentedly high flood; had the flood been of only an ordinary dimension, it is extremely probable that the bridge would have stood.

6. I think the hyphothesis put forward by Mr. Norfor is entitled to much consideration, and I would add that it suggests but another argument against a masonry bridge, unless indeed Portland cement be substituted for mortar.

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From the Executive Engineer, No. 1 Range, to the Superintending Engineer, 5th Division, dated Cuddalore, 25th December 1871, No. 870.

I HAVE the honour to inform you, in answer to your demi-official of the 16th instant, that the river Vellaur is likely to be dry enough to permit of the foundations of the bridge being examined after the 15th January, and until, not later than, the end of February; of course you know the river is tidal there, and it is never quite dry; there is at all times a width of about 200 out of the 500 feet between banks under water, averaging from 5 to 8 feet in depth. I think as soon after the 15th January as possible the examining Committee should be there.

2. I was at the bridge on the 15th to see if any sort of examination could be made; the water was not as low as I should have wished, but I saw much more than I did on the previous occasion.

3. As far as I can judge the foundations and flooring of the bridge are undisturbed, except in the centre of the river where the flooring seems to have been torn up between two large masses of fallen masonry; this has been done *since* the fall of the bridge by the action of the current consequent upon the obstruction caused by the massive blocks of masonry.

4. I am perfectly convinced that the failure of the bridge is not due to any undermining of the foundations, or defect in either materials or workmanship.

5. If you remember it was reported that the second arch from the south abutment was the first to fall in, and I am now satisfied that this assertion is substantially correct. On inspection I found that the second pier, from about 4 feet above floor level, has been moved bodily forward about a yard and a half down stream and then turned over on its north face; the whole mass is now lying in one large block very little injured, and the lower bit of it (pier) was clearly visible though under water, also in an uninjured condition, except that it had sunk a little on the side the pier reclined in turning over.

6. In fact, there is every appearance of a heavy floating body having struck against the pier and thus displaced it. I do not think the action of the current alone could have done this, and it is said * that large trees were washed down the river from Bowangherry; in fact, when I was there the second day after the bridge came down, I saw whole *topes* of plantain trees coming down.

* Proofs now exist.

7. It may be asked why the pier should have given way, or rather separated from the lower portion as it has done, and not all knocked to bits by the shock. I think I can see cause for this, and I must candidly give you my opinion. I have come to the conclusion, after mature consideration, that the old and more recent work in this second pier (from south) could not have set or bound together; it must be remembered that this pier had all its foundations laid, and we finished off the season of September 1869-70, leaving it 4½ feet above floor level, and in this year 1871) we commenced to build over the old work and to raise the pier.

8. That the old and new work is good and both properly set in themselves there can be no question, as the solid compact blocks of masonry lying there will bear evidence.

9. The only conclusion I can arrive at is that probably from the fact that the old work was exposed to the action of salt water for nearly two years (daily submerged) the new mortar did not adhere to the old work, though in every case of new work over old the practice was to remove the top course of bricks off the old masonry before building a fresh one upon it; this has always been my plan of action in such cases, and I have always considered and found it the safest and most sure means of securing adhesion between old and new work. I admit that my experience does not embrace work executed in salt water, but I had no reason to anticipate other than the usual satisfactory result in this case.

10. I am thoroughly persuaded that this, and this alone, is the cause of the failure of the bridge; the excellence of the brick and mortar and workmanship is apparent to all; the large masses of well-constructed masonry lying in the bed of the river speak for themselves; all the work, with the exception of the two last arches, turned in the end of August, which bear the appearance of not having set, is undoubtedly good, and these two arches, it must be remembered only so recently finished, were exposed to the fury of the cyclone, the intrados subjected to the action of waves raised by the furious wind when the mortar joints were probably cleaned out to a very considerable extent.

11. It may be said that the arches should not have been proceeded with at so late a period of the season, and to this I have to say that the late Colonel Boileau and myself consulted together on the advisability of stopping with the fifth arch for the season, and we came to the conclusion that, in the absence of abutment piers, any temporary arrangement to act as a counterpoise to the last arch finished would be extremely hazardous in a river such as the Vellaur; the idea was, therefore, abandoned, and every exertion made to finish the whole eleven arches in the season, which I did.

12. I acted for the best, and I even now think it is the best that could have been done under the circumstances; we anticipated neither the cyclone nor such an exceptionally high flood, and but for this and the pier being displaced these two last arches would unquestionably have been standing now.

13. To give you an idea of the volume of water which came down the river on the occasion of this high flood, I will begin by explaining that the bridge over the anicut at Shateatope across the same river, twelve miles up, has a clear waterway of 589 feet, *i. e.*, nineteen arches of 31 feet, with piers 8 feet high, and rise of arch 7¾ feet, the flood registered 13½ feet over crest of anicut (2 feet higher than any flood registered yet), or 2½ feet below crown of arch; the breaches in the Trunk Road on the north approach to the bridge measure 1,300 feet in length, running at an average depth of 8·08 feet, clearly showing that but for these breaches this bridge would have been swept away too.

14. The whole of this water and other drainages below the anicut, as well as surplus from Veeranum tank, had to pass through eleven arches of 45 feet span, giving width of waterway 495 feet against 589 in the other bridge, with 13½ feet height of pier and 11½ feet rise of arch; then again the sea rose very considerably, stranding a large brig within about a mile of the bridge; this, in conjunction with the volume of water from above the anicut, cannot but have been as severe a trial as could well be brought to bear on a new work.

15. To bring it down to figures the result are as follow:—

The Shateatope anicut bridge has a clear waterway of 7,800 square feet; add to this the breaches 1,300 by 8=10,400 square feet, giving in all 18,200 square feet as the area of waterway occupied by the flood of the 7th. Every drop of this water, together with the large Veeranum and other drainages, had, when it arrived at the Moottaloor bridge, an area of 11,011 square feet* of waterway only to admit it, and this is irrespective of the space occupied by the tidal water which at the time was very considerable; it is, therefore, more than probable that this bridge, under *any* circumstances, would not have stood the flood.

* Against 18,200 square feet at Shateatope.

16. In conclusion, I may add that I did all in *my* power to bring the work to a successful issue. I visited it while in progress as often as I could, and while on the work spot my time was always fully given to minute and close examination and inspection to ensure, as far as possible, the best workmanship. On all such occasions, I was seldom in-doors two hours between sunrise and sunset, and many a time have I gone into the wells bare-footed to see how the concrete had set. I have always discharged my duties conscientiously, and the failure of this bridge after all the labour bestowed upon it is very disheartening to say the least of it.

17. The work was inspected by Colonels Foord, Roberts, Boileau and yourself while in various stages of progress, and I have never heard at any time a fault found with it. On the contrary all considered it good.

18. The work was commenced in April 1869-70 with an allotment of Rupees 20,000 for that year; had 30,000 or 40,000 been given instead the bridge would have been completed five or six months earlier, but in that year considerable reductions were ordered by the Government of India under the head of "Communications," and I was told there was not any chance of more money being obtained for that year in the face of these reductions; the consequence was we had got through over 20,000 Rupees by September and the months of December, January, February, and March, *the best season* for working in that year we could do nothing; April 1870-71 too was lost as we were engaged getting ready materials; I dare not begin earlier even to make bricks, etc., as it was not certain that any grant for the prosecution of the bridge would be forthcoming for 1870-71.

No. 613. From the Acting Superintending Engineer, 5th Division, to the Secretary to Government, Public Works Department, dated Cuddalore, 16th January 1872, No. 223.

Referring to G. O., No. 3,140, dated 13th December 1871, and the appointment of a Special Committee to examine the foundations and report on the cause of the failure of the Vellaur bridge, I have the honour to point out that the examination of the foundations will entail a large expenditure, as wells will have to be sunk to form the ring bund round each pier examined. The cost of this with bailing, etc., for each pier will probably be about 500 Rupees.

2. I would myself deprecate any attempt to make use of these foundations for a new bridge ; if it is determined to use them, it is obvious that the foundation of *every* pier must be examined, as it would be most unsatisfactory, not to say unsafe, to conclude that because a certain number are sound the rest must be so also.

3. The examination of all the foundations will entail a very large outlay and occupy much time, and I would say that, even were the most careful examination made to prove satisfactory, it would still be unsafe ; it would be false economy to make use of these foundations, as it is difficult to believe that at least some portion has not been affected by such a flood as that of November, and it is very intelligible that the addition of a heavy superstructure might be the means of revealing a flaw which might escape even the most careful examination.

4. Be this, however, as it may, I would beg to be informed of the intentions of Government, for, as before pointed out, some expenditure must be incurred, and the extent of this will depend on that of the examination.

5. In anticipation of sanction, for no time must be lost, I have directed the Executive Engineer to prepare bricks and material sufficient to admit of the examination of *three* piers, and I beg to request sanction for the payment of the material prepared for the same.

6. I would further beg to be informed *when* it is proposed to make the examination, as there is no need of the Committee proceeding to the spot till all is ready for them.

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No. 614. Order thereon, 31st January 1872, No. 298.

**CIVIL WORKS, No. 27.**

In order to constitute as independent a Committee as possible to inquire into the causes of the failure of the Vellaur bridge, the Government resolve that the Agents of the Madras and Great Southern of India Railways be respectively requested through the Consulting Engineer to be good enough to make the services of an experienced Engineer of the Company available for the duty to be associated with Captain J. Pennycuick, R.E., who will hold himself in readiness for the purpose.

2. Looking to the heavy expense which the examination of the foundations of all the piers of the bridge would entail, the Committee will confine their examination in the first instance to the foundations of the pier that first fell, and the

*Proceedings of the Madras Government, Public Works Department,*
*31st January* 1872.

Government will on the result being reported determine whether it is necessary to examine any more. The Acting Superintending Engineer will make all necessary arrangements for conducting and expediting the examination in anticipation of the assembling of the Committee, and he will intimate to Captain Pennycuick, who is at the Presidency, and to the Agent of each Railway Company, the date on which he expects the site will be ready for examination.

(True Extract.)

Colonel, R.E.,
*Secretary to Government.*

To the Acting Superintending Engineer, 5th Division.
,, Acting Consulting Engineer for Railways.
To Captain J. Pennycuick, R.E.
To the Controller of Public Works Accounts.

Exd. E. C. Shunker.

F.

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# Register of sinking of arches

| | | | Inches |
|---|---|---|---|
| From North | 1 Arch | South | 5½ |
| | 2 | Do | 4¼ |
| | 3 | do | 4 |
| | 4 | Do | 3½ |
| | 5 | Do | 3½ |
| | 6 | Do | 5 |
| | 7 | Do | 4½ |
| | 8 | Do | 4 |
| | 9 | Do | 3½ |
| | 10 | Do | 4 |
| | 11 | Do | 3½ |

In pitching the arches an allowance of 3" was made for sinking-

(True Copy)

John Pennycuick Capt. M.E.
Ex. Er.

4109
3658/72

No. 136.

Executive Engineer's Office
Camp Pulkanoothu 1st June 1872.

From

Captain J. Pennycuick R.E.
Executive Engineer in charge of
Dindigul Range Madura Distt.

To,

The Secretary to Government
Public Works Department

Sir,

I have just received your telegram of the 27th ultimo regarding the Vellaur Bridge report.

2. It would be a useless waste of time and money to reply by telegraph, as the post is as quick.

3. The draft report was forwarded by me to Mr. Logan on the 6th March 1872. (4 days after the final examination of the Bridge) but the papers were not returned to me by Mr. Robinson, the other member of the Committee, until just as I was leaving Madras at the beginning of April.

4. Since then I have been so much on the move (having had to go first to Madura and then to Dindigul) and have been so occupied with taking charge of this enormous range, that I have not been able to attend

to the papers again until quite lately.

5. Moreover the difficulty of getting any clerical assistance in Dindigul is so great (the range establishment being quite unequal to its ordinary work) that it is only by the courtesy of the Sub-Collector that I have been able to get the papers copied at all. The fair copy is now being written, and I expect to receive it daily.

6. As soon as it is completed it will be forwarded to Messrs. Logan & Robinson for signature and the latter will be asked to forward it direct to you.

7. I warned Col. Carpendale that my leaving Madras to take over a range in Madura might very likely lead to some delay in the submission of this report; but his reply was to the effect that this was of less consequence than the loss of my services by my remaining in Madras.

I have the honor to be

Sir

Your Most Obdt. Servt.

John Pennycuick Captain R. E.

Ex Engr. in ch: of 2nd Range

Madura

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[illegible]

P. W. 1872 ~~[illegible] Dept~~

No. 136. ~~[illegible]~~

From Pro. ~~[illegible]~~ No. 2758.

The Executive Engineer

In charge of Dindigul

Range Madura

To

The Secretary to Govt.

P. W. Dept.

Dated 1st. } June 1872.

Recd. 4th. }

Explaining cause of delay in submission of Vellaur Bridge Report.

No. 32

No. 2427-2428. 15th Octr. /72

No. 261

45 @ 12

No. 100.

Supg. Engineer's Office, 5th Dn.
Camp Salem 21st August 1872.

From

The Superintending Engineer,
5th Division

To

The Secretary to Government
Public Works Department.

Sir,

Enclosures 10.
2 Plans.
8 Reports.

I have the honor to return the Committee's report and other enclosures in your letter of the 10th of August No. 107 with the following observations on the construction and fall of the Vellaur Bridge.

2. The plans and estimates for the four bridges across the Pooniar, Paravanar, Vellaur and Coleroon, on the coast road, in the South Arcot District, were prepared by the late Colonel Lawford, at the time he had charge of a portion of the South Arcot District in addition to Tanjore and Trichinopoly. The bridges across the Pooniar and Paravanar were commenced

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in 1855 and completed in 1857 while I was District Engineer of South Arcot. The Coleroon bridge was built at the same time by the Public Works Department of Tanjore. The water way allowed for these bridges has proved to be quite sufficient, and they have not up to this time sustained any damage from floods. The bridge across the Vellaur was not commenced till May 1857 but nothing was done that year, except collecting some materials, as the mutiny put a stop to that and all other new works.

3. The bridge, as originally designed, consisted of ten arches of fifty feet span on piers eight feet high. There were to be no wells in the foundation, as it had been assumed that the bed of the river was firm clay. When I ascertained that the bed of the river was only sand, I prepared fresh plans and estimates first for a bridge of eleven arches of forty five feet, and afterwards for a bridge of nine arches

of

of fifty five feet with foundations on wells. The former was the design adopted in 1869 with some additional height to the piers. There was also prepared at the suggestion of the late Colonel Ouchterloney a plan and estimate for an iron screw pile bridge, as one of the works to be undertaken by a Land and Building company that he was trying to get up. I also wrote to a Calcutta firm for an estimate for a screw pile bridge. But the price for which they undertook to erect a bridge of that kind was more than double the estimate for a brick bridge. As there were no facilities for constructing an iron bridge in the District I gave up the idea of having one.

4 The building of the masonry bridge was commenced in April 1869. In that year, the two abutments were built also the two piers at the South end with their floorings and retaining walls. By September the allotment of funds was expended, and no more work could be done till the next Official year. I

saw

saw the well sinking at the South abutment in progress and I saw the work again in January 1870. In April I gave over charge of the Division and was absent on furlough for two years. The work was resumed in April 1870 and, during the next twelve months, four piers at the North end were built with their floorings and retaining walls. Thus, at the expiration of two years from the commencement of the bridge, there remained to be built four piers from their foundation with floorings and retaining walls.

5. This being the case, when work was resumed in April 1871, it would have been more judicious, considering that the best part of the working season was over, to have confined the operations of the year to the completion of the piers and abutments and the preparation of materials for arches and centerings, leaving the arches to be turned in the first three months of 1872, the only months of the year

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in which, as a rule, the river is free from freshes. All the brickwork of the piers and abutments would then have been thoroughly dry. Even those built in 1869 were raised a foot and a half at the last. Instead of this, the building of some of the piers from their very foundation and the turning of the arches were going on at the same time, and by the middle of August the last arch was completed

6. The Committee are of opinion that the immediate cause of the destruction of the bridge was the failure of the foundation of the third pier from the North end, but do not attach much importance to the settlement of the question which pier first gave way. I submit however that it is a matter of very great importance, for, if the failure of the bridge is due to inadequate foundation and contraction of waterway, the portion of the bridge that might have been expected to be the first to give way would be one of the two piers at the South end as the stream sets so strongly

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strongly against the South bank of the river. The Committee however report that the most careful examination showed nothing wrong with the foundation or flooring of the two Southern piers. The deep hole below this part of the bridge, mentioned in a separate Memorandum, may have been scoured out after the fall of the bridge.

7. The Committee remark on the low rate allowed for the brickwork and the inadequate thickness of the arches. The rates in the estimate were those which had been proved to be sufficient, and during the progress of the work supplemental estimates were submitted and sanctioned. High rates alone do not secure good work. The best works in the District have been the cheapest, the goodness and the cheapness being due to the same cause viz/ continuous good superintendence. The depth of the arches at the crown 1'-10½" or two and a half bricks, is that which has always been given in the district to arches of forty five span. I may

mention

mention that as regards thickness of piers span rise and thickness of arches the Vellaur bridge was an exact copy of the Poonear bridge at Cuddalore built fifteen years ago.

8. The foundations of the Vellaur Bridge, according to the Estimate and Specification, were to be ten feet deep, of which five feet were to be of solid masonry and five feet of brick in chunam wells. The wells were to be filled in either with brick cubes or with concrete. There were to be floorings one and a half feet thick between the piers with retaining walls above and below built like the foundations of the piers, that is five feet of wall on five feet of brick in chunam wells. The foundation was to be ten feet below the lowest part of the bed of the river, or about fifteen below, for more than half the breadth of the river. There is no bridge, annicut or other river work in the District which has deeper foundations where the bed of the river consists, as in this case, of loose sand. If any of the wells were not filled with concrete,

or

or with brick cubes, then the work was not in accordance with the estimate and specification.

9. The waterway allowed for the bridge was in accordance with the section of the river at the time the original design was made. Since then from the stream setting strongly against the South bank the deep bed of the river has been moving year by year more to the South, and the breadth of the river at the site of the bridge has been increasing, but I did not consider that any reason for increasing the waterway of the bridge. It is true that the Executive Engineer once suggested that the bridge should have two more arches, but on my asking him to examine the river above the site of the bridge, he wrote to me and expressed him=self perfectly satisfied with the water=way determined on. It is mentioned in appendix A that the breadth of the river 500 yards above the site of the bridge where the bank

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is high on both sides is 452 feet, while the clear waterway of the bridge is 495 feet and the distance between the abutments is 555 feet.

10. I have known several instances of a needlessly large bridge having been designed, from taking the breadth of the river at only one place as a guide for the length of the bridge. The bridge designed by the Road Department & sanctioned by Government, for the Poo=niar, on the Trichinopoly road, was to have 45 arches of 45 feet span on piers eleven feet high while the bridge actually built over the same river at Cuddalore, twenty five miles lower down, has only 19 arches of 45 feet on piers 6 feet high. The bridge sanc=tioned for the Mullatar on the Trich=inopoly road was to cost 42,000 Rupees but the bridge I built seven years ago cost with its long gravelled embank=ment only 6,000 Rupees.

11 I attribute the fall of the Vellaur bridge to its having been

exposed

exposed to an extraordinarily high flood, immediately after its completion, and before all the brick work was thoroughly dry. I believe there was sufficient waterway, and after the construction of groynes on the South bank the cross section of the river would have been improved and the capacity of the bridge increased. This is the only case of the total failure of a large new work in the South Arcot District during the last seventeen years. The other large bridges and annicuts having been completed without any accident during the progress of the work.

I have the honor to be,
Sir,
Your most Obedt. Servant

E A Ward Coll. R.E.
Supg. Engineer, 5th Divn.

P. W. 1872 Depart
From No. 4109
The Supg: Engineer,
5th D.

To The Secy: to Govt:
D. P. W.

Dated 21st }
Recd: 24" } Augt: 1872

No. 100.
Encls: 8 + 2 Plans.

Returning the Com=
=mittee's Report &ca.
with certain Observa=
=tions on the Construc=
=tion and fall of
the Vellour Bridge
in South Arcot.

No. 2427-2428-15 Oct. 1872

262
No. 263

[illegible]

Vellaur Bridge. 50 5718

Memo: to accompany the Report of the Committee appointed to examine into the causes of the destruction of this bridge. by D. Logan.

In the interval between settling the draft of the Report in question, and its receipt and reperusal (within the last few days) for signature, a few remarks in amplification of the subject have occurred to me; and as, at this date, it would entail undesireable delay in rendering the report to await the concurrence of the other members of the Committee to incorporating these remarks in the report itself I make them the subject of this memorandum for which, of course, I am alone responsible.

With reference to the faultiness of design in the bridge, I am of opinion that the chief fault lay in the shallowness of the foundations. In the sandy bed of a river subject to heavy and rapid floods the foundations were carried only 10 feet below the bed of the river. The lower 5 feet of these foundations consisted of wells built of brick in mud. The wells were as described to me by the native overseer who attended the Committee at the site of the bridge, filled with concrete in the following manner. A basket full of broken brick and another filled with lime and sand were held

opposite and close to each other over the open well full of water, into which the contents of the baskets, made to intermingle as they fell, were then poured. If this is a correct description of the mode of laying in the filling of the wells, it is scarcely possible that any cohesion existed in the filling, which it was an object to make into a solid mass.

Had the foundations of the bridge been carried down about 20 feet below the bed of the river, with wells properly constructed, I believe that in spite of insufficient waterway and other defects the bridge would have withstood the flood which destroyed it.

In support of the opinion that the foundations were too shallow I may point to the fact that I found a large hole scoured out of the bed of the river (immediately below the bridge and near the south bank of the river) to a depth of 17 feet below the flooring ~~of the~~ or 7 feet below the lowest part of the foundations.

With regard to the quality of the brickwork I believe that its unequal character was due to the want of the close supervision of an Engineer officer rather than to the lowness of the price allowed. No doubt a price for

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work, out of which there is little or no profit to be honestly gained by suppliers of material and labour holds out a premium for roguery, yet without close and conscientious supervision, in my experience, the price may be one & out of which a large per centage may be profit, & the work will be utterly bad.

In making these remarks I would guard against its being supposed that I am blaming the Executive Engineer, in the present case, for want of supervision, which under the circumstances detailed in the Committee's report it was impossible for him to afford. I am speaking of the system, and of the work as it was opened up to me as it never could have been to the Executive Engineer; the fallen piers & broken arches laid bare more than could have been seen on occasional visits of Inspection, however conscientious, during construction; and it seemed probable to me that the unequal quality of the work pointed out, the better kind, when the Engineer had been expected, and the worse, the time of his departure and absence

There was evidence, in this way, that some one on the work knew what good work is - the maistry or overseer or both - for some of the

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brickwork exposed was fairly good, while other parts were so bad that I was able to pull out by hand the bricks from what, called Chunam, was in reality little more than sand — Again on the north bank of the river a full sized diagram of one of the arches was laid out on the ground, in Chunam, shewing all the bricks and joints distinctly laid in a workmanlike manner, and had the arches been built throughout according to this pattern, no better work, with the materials available could have been executed —

I am quite confident that on every work of the magnitude and importance of the Vellaur Bridge it would be a measure of real economy to appoint an Engineer to be resident on the work, or at all events to be able to inspect the work thoroughly every two or three days — In no other way in my opinion can sound and really good masonry be ensured in this Country

Such a system would give a real instead of a nominal super-vision, and would at the same time bring prices for work and material into a natural and healthy condition; for all chance of profit through dishonest work being at an end no contractor

would be found to take work except at fairly remunerative prices, & in this way Govern-ment would not only come to realize the cost of honest and sound work, but one strong motive for dishonesty would be removed from Contractors, and others engaged and associated with them.

Owen Logan
Chief Engineer G. S. I. Railf.

Camp. Dindigal
24th June 1872.

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4109
P.W. 3638/72.
Pro: 15th October/72 Lr. B. No. 2263

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# Memo to accompany Vellaur Bridge report

There are many opinions expressed in the report with which I do not agree, but I pass them over as Mr Logan's Memo, every word of which has my entire Concurrence, explains fully the Cause of the failure of the Bridge. One remark however is made in para 30 that demands notice. It is there stated that "good and bad are altogether comparative terms, and can only be used with reference to the price paid, the object for which a work is intended, and the Circumstances under which it is executed."

To works of different magnitudes different classes of masonry are suitable, but goodness

and

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and badness are inherent qualities, and do not depend on extraneous circumstances.

W. R. Robinson
Ac. Dep. Chief Engineer
Madras Railway

Madras.
July 25th 1872

3/202/72

P.W. 3638/72.
4109
Recd 15th Oct/72 L. Bk No. 263

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Memorandum by the Chief Engineer of the Public Works Department.

The Vellaur Bridge Committee state that "the Bridge "failed through faultiness of design "and not primarily through any "defect in material or workmanship".

The Supt Engineer who designed the Bridge ~~as positively~~ "attributes "its fall to its having been exposed "to an extraordinarily high flood "immediately after its completion, "and before all the brick work "was thoroughly dry".

The theoretical grounds on which the former base their opinion are 1st. the insufficiency of waterway

with

with reference to the Drainage area. The latter being taken at 2,800 square miles, the waterway up to the Crown of the arches is 3·95 square feet per square mile, and up to their springing 2·39 square feet. Provision having also to be made for Tidewater and surplus of Tanks fed from the Coleroon.

2ndly The insufficiency of water-way with reference to the width of the River, ~~3~~ 495 feet clear of piers being allowed to a section at ordinary high flood level stated to have been 666 feet in 1862 and 753 in 1869; or natural water section of 4973 square feet at ordinary high level calculated at 15·3 above the flooring level, and 8509 square feet at the level attained when the Bridge gave way, as against 6682 square feet provided up to springing of arches, and 11,056 square feet up

to

to their crowns- The flood level when the bridge fell being estimated at 17 feet above flooring level, and a foot or more afterwards-

3rdly Insufficiency of depth of foundation wells-

4thly Insufficient thickness of arches-

The actual facts which the Committee report with reference to the Bridge, are that the up-stream end of the 3rd pier from the South side, built in 1870-71, had sunk considerably and that the down end had been raised; the combing of the pier being visible three inches above the floor level, and portion of the curtain wall and flooring of the arches on the both sides being destroyed- Half the length of this pier, for its whole

height, was separated vertically
from the remainder of the Pier, and
had fallen obliquely upstream
to the north west. Of the other Piers
the 1st and 2nd from the north side
had fallen southwards, and
every other pier northwards.
The separation in all but the
3rd Pier had taken place within
2 feet of the floor level and each
had separated into 3 or more
parts, the fractures having been
horizontal.

These facts can lead to no
other conclusion but that arrived
at by the Committee in their
20th para viz that the imme-
-diate cause of the destruction
of the bridge was the undermining
~~[illegible]~~ of the 3rd pier from the
north

73 26

North on the upstream side. Its sinking caused the fall of the third arch, (not the 2nd) the upstream half falling towards the north side) and the thrust of the arches over-threw the other Piers in succession. No further examination of Piers was required; the 3rd Pier was accurately detected as the faulty one to be examined; while the hearsay evidence which led to the examination of the two southernmost Piers viz "that the 2nd arch "from the south was heard to fall "with a crash, at about 2. A. M on "the morning of the 8th November 1871" was ludicrously defective. The Supt Engineer's theory that the pier that might have been expected to give way was one of the

two

two southernmost, must yield before the established fact that it was the third Pier from the north the foundations of which were undermined; the point to which he rightly attaches great importance has undoubtedly been settled.

The accuracy with which the particular manner of failure has been settled, leaves also no doubt but that the Committee are justified in attributing it to defective design. The only remaining question is in what was the design defective. And the only defect conclusively established by the facts reported by the Committee is that of insufficient depth of foundation wells. What further defects there were is matter

of conjectural opinion -

My own is, that Col. Foord's design was a bold one having reference to the drainage area above and River section, but warranted by the experiences of the last 17 years detailed in paras 8, 9, 10 and 11 of his Report - Had he been bolder, and omitted the flooring and wells between arches so as to allow of an even scour through them all I consi-der it possible that his Bridge might have stood; and that it certainly would, if besides such omission, the pier foundations had been laid 10 feet deeper - The state of a River bed composed of pure sand, after subsidence of floods

gives no clue whatever to what might have been its state during the prevalence of floods. The deep pool on the south side, and general deepening of the rest of the bed, shown in the section taken in January 1872, at a point 93 feet below the Bridge site, are probably due to the overfall of the water from its ruins, acting with most force where the dry weather set of the stream occurs. During the high flood, as the facts show, the action was strongest and deepest near the north side. And this is probably due to wash caused by recession of tidal water in the next lower bend of the river along the north bank. The action of the tide, I should to have been detrimental

77 28

only when receding, and have no doubt but that it was during its ebb that the failure occurred, if the hour has been correctly reported - For during its flow it would undoubtedly counteract undermining action of the River current. No extra provision of waterway was needed for surplus of Tanks supplied from the Coleroon as arrangements are doubtless always made for shutting off the extra supply of water on such occasions.

The thickness of arch used is practically demonstrated by Col. Foord to have been sufficient for a well built Bridge designed to bear the ordinary

weights of Indian Road traffic, though insufficient for Railway purposes.

The Committee having satisfied themselves as to the cause of the failure of the bridge, and that it was not owing to defect in material or workmanship, I do not feel at liberty to follow them in their comments on rates and supervision, which are evidently beside the mark in this instance.

C. W. Walker Coll. R.E.
Chief Engineer
D.P.W.

19th September 1872

79 29

No. 2427 P.W.D. 81

Civil Works 30

Pro. of the Madras Govt.

Read the following:-

From Capt. J. Pennycuick R.E. (H.E. No. 1360) 1 June 72

From Committee appointed to investigate into the causes of the destruction of the Vellaur Bridge } — H.E. dated ———

From the Supg. Engr. 5th Dn. (H.E. No. 100) 21 Aug. 72

Ordered that the Report of the Committee on the Vellaur Bridge, the letter from the Superintending Engineer 5th Dn. and the Memo: from the Chief Engineer P.W.D. be communicated to the Government of India in continuation of letter No. 146 of 17th January 1872.

The Governor in Council offers his best acknowledgements to the

Gentlemen composing the Committee for their most lucid exposition of such facts connected with the Bridge as could throw light on the cause of its fall. He accepts their conclusion generally, viz that the cause of failure was defect of design and not of material or workmanship - He admits at the same time that the Superintending Engineer's former experience justified his belief in the sufficiency

of his design, except as to depth of foundation of the piers - And he is glad to + receive such competent testimony as has been given to the general character of the Bridgework, which reflects considerable credit on the Executive Engineer Mr. Norfor and on his Overseers and other subordinates.

The attention of all Superintending Engineers and Range Officers will be called to former Government orders prescribing the submission of detailed reports as to drainage area

+ I do not think he can quite go so far in the Mr. Logan's minute before us: concurred in by Mr. Robinson. We might say + "And he is glad to find that the Executive Engineer Mr. Norfor is in no way to blame for the destruction of the Bridge - ~~Hts~~ ~~on the case~~ having done all that lay in his power to ensure its better construction."

A. A. [illegible]

Rainfall, fall of River &c with accurate cross sections and borings at the site, to accompany all plans and estimates for Bridges of any importance. The amount of superintendence required and available should also be matter of special report. A Plan with Estimate of Rs. 70,000 (not including abutments or carriage of materials from Madras) prepared by the Superintendent of the Government Work shop for a Bridge of 12 Iron girder spans

85, 32

of 50 feet each, on Screw Pile Piers will be forwarded to the Superintending Engineer 5th Divn for consideration of the Local Funds Board; together with similar papers sent in by Mr De Closets for a Bridge of 5 Cast Iron Arches of 100 feet each, on Masonry Piers, to cost from Rs 96,000 to Rs 120,000

His Excellency the Governor in Council cannot ~~but~~ consider as ~~un~~satisfactory the explanation given by Captain Pennycuick of the very great delay

I would omit this last paragraph; It can do no good.
R. A. regrets that he —

that has occurred in submission of the Report of the Committee of which he was a Member - The draft appears to have been made out on the 6th March (4 days after the Committee sat) and returned to him by the beginning of April; but not to have been fair copied for two months, or finally received in the Government Office till the end of July - Any difficulty in having it transcribed would have been obviated

87 33

had he simply re-
=presented his need
of assistance and
sent the original Draft
to be copied in the
Secretariat Office -

G.M.W.

170/12

To

5 the Committee for the Exn. of the Vellaur Bridge

(the Committee for the Exmn. of the Vellaur Bridge)

130 " Supdg. Engineers

2 " Major R. B. Kennedy

(Major R. B. Kennedy)

" Finl. Deptt.

" Supg. Engr. for Ports & Convns. *

* Desp. 23/1/73 with a copy of letter to the Govt. of India -

Desp. to all 25/10/72 Except the 5th Dn.

Desp. to the S. Engr. 5th Dn. with 1 plan, 1 estm. & 1 specn. connected with Ch. 1909 of 1872 & 1 plan of (estm. & specn.) connected with Ch. 2621 of 1872. 28/10/72

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Civil Wks

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No. 2428

To. The Secretary to the Govt.
of India, P. W. D.

Sir,

I am directed, in continuation of Colonel Carpendale's letter No. 146 of 17th January last, to communicate for the information of the Government of India the Report of the Committee on the Vellaur Bridge, an explanatory letter from the Supg: Engineer 5th Division,

and a Memorandum by the Chief Engineer of the Public Works Department.+ And I am to state that this Government have accepted the general conclusion arrived at by the Committee, viz that the cause of failure was defect of design, and not of material or workmanship; admitting at the same time that the Supt Engineer's former experience justified his belief in the sufficiency of his design, except as to depth of foundation of the piers.

The destruction of the Bridge is attributed by the Comm^ee. to the insufficient depth of the foundations. ~~The correctness of this conclusion is accepted by the Govt.~~ Inadequacy of water-way was also a material defect in the design of the work - but two of the members of the Committee have recorded their opinion that the Bridge would never-theless have withstood the flood to which it was exposed immediately after its completion, if the foundations had been carried 20 feet - instead of only 10 feet - below the bed of the River - The materials & workmanship are described by the Committee as "much better than the ordinary run of departmental work." Though he need

inferior to the standard required by Railway Companies - and as good as could be expected, considering the price paid & the supervision exercised - The Comm^s further comment on the inadequacy of the superintendence during the construction of the work -

I am to state that the Govt accepts the conclusions of the Comm^n: as to the cause of the accident. For the prominent errors in the design - insufficiency of foundation and inadequacy of waterway the ~~the~~ Sub J. Eng^r is answerable. But in his defence it must be considered - as urged by him - that no other work in the District ~~on~~ in loose sand has deeper foundations - and that the waterway was sufficient according to his calculations & experience - Several other bridges have been built in similar position on the same line of road &

93 38

been stood well. Under these circumstances the Govt is not inclined to attach blame to Col. Ford for the loss of this bridge, much as it is to be regretted - Care will be better in future to guard against the error committed in this case. It is clear that no blame attaches to the Executive Engr. - Mr. Kerr for- it being admitted that so far as material be are concerned, the bridge was substantially constructed. under considerable difficulties. As regards the amount to be made available - ~~(which certainly was deficient)~~ - the Govt need hardly point out the impossibility of rebuilding as much agency of this character as the Comrs. deem necessary. The P.W. Est: of this Presidency is far too limited in

in number. - the area of country
over which it has to operate is too
large - the number of works contracted
for is too great - the work of special
officers being cleared for any but
the most important works - so the
present case the director of the
Comp. is practically of no great
weight - for it is admitted that
the work was sufficiently well
performed - the defect being in the
design - but in the construction. It
would certainly be ~~more~~ very desirable
to the govt. if they ~~could~~ afford to employ the
extensive agency - & pay the high rates which
Railway Companies do - but this
is beyond their means - and so long
as the work performed for govt. is - as
in this case - good except for its timber -
it would be a waste of public money -

to strive for here. A bridge of which
it can be truly said, that if its
foundations had not yielded – it
would, notwithstanding deficient
waterway, have stood an extraordinary
flood within a few days of its
completion – is certainly built
well enough for every practical
purpose. And the Govt. – with its
limited funds and agency
~~and~~ would hardly be justified
in ~~striving for~~ aiming at here. Under the
new Organization it will, it is
hoped, be in the power of Govt. to pro-
vide special agency to a greater ex-
tent than has hitherto been the
case – but still in the position of
Railway Engineers – with extensive
agency and ample funds – have
a very imperfect idea of the

difficulties with which the Engineer

driving [of pit] has to contend in ~~the~~ ...

~~[illegible]~~

It will be observed that the Committee comment in strong terms on the inadequacy of supervision during the progress of the work – and the inefficiency of

17 38

2

The attention of all Supg. Engineers and Executive Officers has been called to former orders prescribing the submission, together with Plans and Estimates of all large bridges, of detailed in-formation as to Drainage area, Rainfall, fall of River &c.a and of cross sections and borings.

3

It will be observed by the Govt. of India that the Committee, while expressly stating their opinion that the failure of the bridge was not primarily

owing to any defect of
material or workman-
-ship, but that the
masonry was decidedly
as good as could be
expected, and was
highly creditable to the
Executive Officer, have
deemed the conditions
under which the work
was executed so extra-
-ordinary as to justify
their [going out of their
way to] expostulating
with this Government
as to their existence.
With reference to which
I am directed to point
out that unfortunately this is the
normal state of cir-
-cumstances with
which

which the Public Works Officers of the Madras Presidency have to contend in carrying on their labours: and is the inevitable consequence of the scattered nature of their work, and the (mo-derate) limited establishment maintained in com-parison ~~to~~ with the area of charge.

4 This particular subject of bridge building meets neces-sarily with different treatment at the hands of an Indian Engineer (of the old

obliged &

school) accustomed to make the most of low rates and small sanctions, and at those† of ~~the~~ English Railway Engineers, accustomed to design structures calculated to stand every possible strain, and able confidently to rely on the necessary funds being promptly and amply supplied. Hence the astonish-ment of the latter at the excellent nature of work turned out, at rates and under an amount of super-vision, unprecedented in their experience.

† inadequate supervision

This para had better be omitted - as in this instance the bridge fell a few days after completion
JDS

While the Public Works Officer cannot but take credit to himself for the generally satis-factory result which he achieves with his limited resources.

5. In the particular case in question, out of the entire sanction of Rs 53,930, Rs 19,931 were laid out in 1869-70 when the two abutments and one pier were raised 12 feet in height, and a second pier to a height of 4 1/2 feet; in 1870-71 Rs 14,785 were spent, three piers raised 13 1/2 feet, and a fourth

6 feet; the remainder of
the work being carried
out in the first 6 or
7 months of 1871-72-
Taking these figures
into consideration,
this Govt., I am directed
to say are not prepared
to admit that under
the circumstances
in which funds are
usually obtainable
for the Public Works
of the Madras Pre-
-sidency, this was a
case in which special
supervision could
well be set aside
from other general
duties for its sole
performance - Nor

(10524)

in general terms, are they prepared to meet such a rise of rates and increase of establishment charges as it would appear to be the Committee's intention to recommend for adoption.

GMW

28/2

Despd. 25/10/72 with a copy of G.O. no. 2427 of 1872.

35 spare copies of G.O. no. 2427 of 1872 despd. to the Govt. of India by Book-post 28/10/72.

obt. of (1872) Madras.

PUBLIC WORKS.

The Committee for the Examination of the Vellaur Bridge
&
The Secretary to the Govt. of India

Encl. 3

G. O. 15th Octor 1872, 2427-2428.

Nos. 261 @ 264 & 265.

...idge, South Arcot

...Passing orders ...ting to the ... Vellaur ...vember 1871

...ding, with re-...arks, Report of the Com-...ittee on the failure of ...ridge on the South Arcot ...November 1871.